VII. Ground Water Quality: Out of Sight Not Out of Mind

How Does ADEQ Characterize Ground Water?

Ambient Ground Water Monitoring Program – ADEQ's Ambient Ground Water Monitoring Program has multiple objectives for its monitoring program. These objectives include:

- Fulfill legislative mandates to monitor aquifers to detect the presence of new and existing pollutants, determine compliance with applicable water quality standards, determine the effectiveness of implemented Best Management Practices, evaluate the effects of pollutants on public health or the environment, and determine water quality trends;
- Characterize regional ground water quality;
- Determine impacts from specific anthropogenic (human caused) sources.

Ground water sampling is conducted by ground water basin to examine regional ground water quality. There are 51 ground water basins recognized by the Arizona Department of Water Resources. Since 1995, ADEQ has completed 10 ground water basin studies, has ongoing studies in 13 more basins, and intends to start three more basins this year **(Figure 35).** Data collected by this program are provided to the well owner and incorporated into ADEQ's Water Quality Database. A comprehensive report and a summary fact sheet are published for each basin studied. These can be obtained and downloaded from ADEQ's internet site at: www.azdeq.gov. These studies are also reflected in the ground water quality monitoring maps provided in this report. Note that the wells sampled are not evenly distributed across the state. Areas where basin studies have been completed will have a much greater volume of data, whereas other areas may have little or no data at this time.

Selection of basins for investigation are based on a number of factors, including watershed rotation schedule (see Chapter VIII) and development pressures in the basin that may be impacting ground water quality. Systematic, grid-based random sampling is conducted to investigate potential nonpoint source pollution impacts on ground water quality. Higher density sampling occurs around targeted land uses to determine their affect on ground water quality.

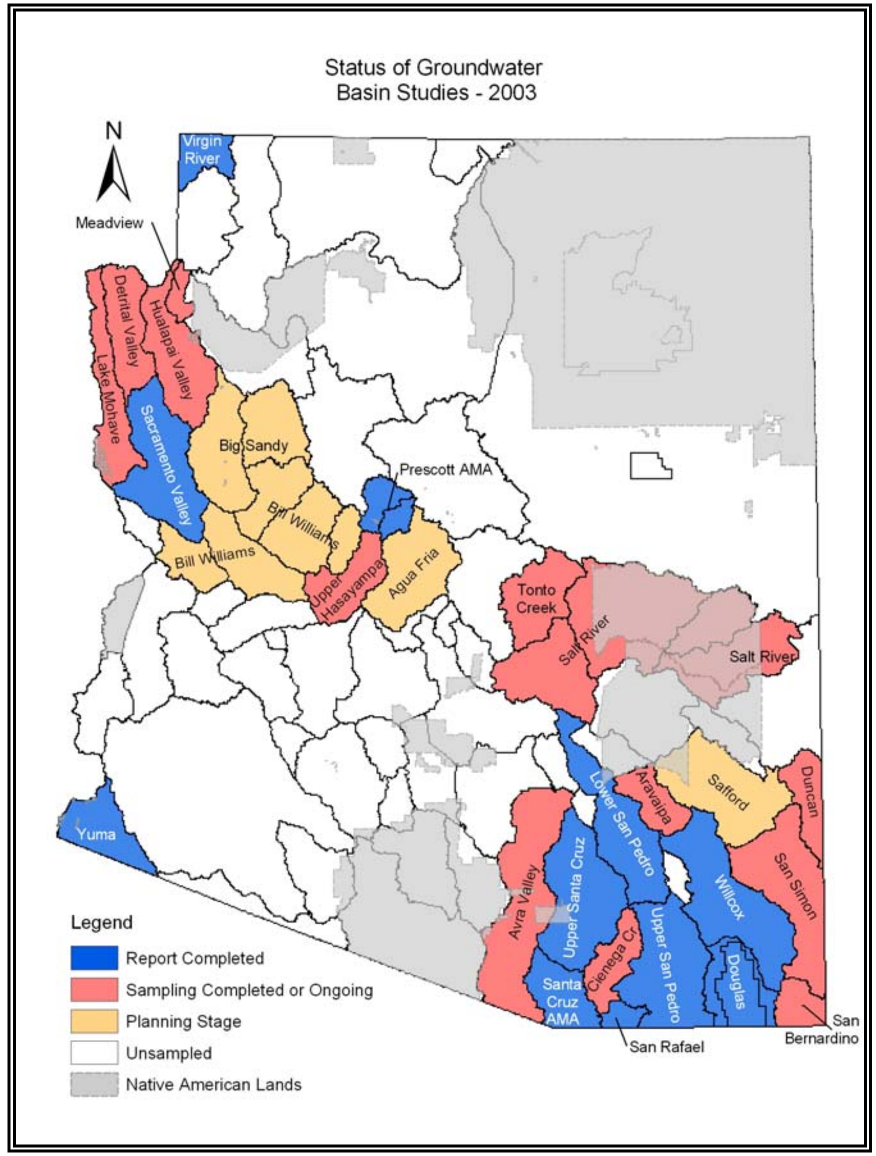

Figure 35. Ground Water Basin Studies

Basin studies are sometimes conducted in collaboration with other internal and external monitoring programs. The internal programs include the Pesticide Contamination Prevention Program, the Border Program (Mexico border), and the Aquifer Protection Permit Program. The U.S. Geological Survey has been ADEQ's external partner.

Inorganic constituents (see list in text box) are collected at each site, while samples for Volatile Organic Compounds (VOCs), pesticides on Arizona's Ground Water Protection List or banned pesticides, radionuclides, bacteria, perchlorate, and other constituents were collected in areas where these parameters are likely to be encountered. Samples for oxygen, hydrogen and nitrogen isotope analysis are collected at certain sites to assess aquifer recharge characteristics. Based on the ground water sampling results and statistical analysis, index wells are selected which will be re-sampled in the future to determine ground water quality change over time.

Inorganic Chemicals Tested

Antimony	Beryllium	Cyanide	Nitrate
Asbestos	Cadmium	Fluoride	Nitrite
Arsenic	Chromium	Lead	Selenium
Barium	Copper	Mercury	Thallium

The Ambient Ground Water Monitoring Program provides important information to the public, including an overview of the ground water quality within a basin, areas where specific ground water quality problems can be expected to occur, and whether there has been any change over time in the ground water quality of the basin. This program is particularly important in evaluating effectiveness of nonpoint source pollution control by its broad, regional approach to monitoring and assessment of water quality.

Pesticide Contamination Prevention Program – This state-mandated program is intended to prevent contamination of ground water, soil, and the vadose zone from pesticides used in agriculture. The Ground Water Protection List, established in 1992, includes a list of 152 pesticide active ingredients that have the potential to pollute groundwater in Arizona. Another 37 pesticides are on the list of banned pesticides (e.g, DDT, chlordane, lindane). However, only 22 of the 189 pesticides listed or banned have an Aquifer Water Quality Standard (see text box).

Pesticides with Aquifer Water Quality Standards

Alachor	Chlordane	2,4-D	Endothall	Glyphosate	Lindane	Picloram
Atrazine	Dalapon	Dinoseb	Endrin	Heptachlor	Methoxychlor	Simazine
Carbofuran	DBCP	Diquat	EDB	Heptachlor epoxide	Oxamyl	Silvex
						Toxaphene

The monitoring objectives for the Pesticides Contamination Prevention Program are:

- Determine whether these pesticide active ingredients or their metabolites are present or absent in the soil, vadose zone, or ground water;
- Determine whether an Aquifer Water Quality Standard has been exceeded; and
- Determine if ground or surface water pollution is occurring or has the potential to occur (soil contamination is usually an indicator) from general usage of pesticides.

Monitoring is aimed at providing an early detection to prevent further contamination; therefore, banned pesticides are not normally included in the analyses. Any detection of pesticides results in a follow up investigation, and if an exceedance is validated through follow-up monitoring, enforcement actions may be taken to mitigate the contamination. During the investigation, strict quality control samples (splits, duplicates and field spikes) are collected and tested.

Monitoring results are compared to water quality standards and Arizona Department of Health Services' Human Health Based Guidance Levels for the Ingestion of Contaminants in Drinking Water and Soil and other standards. All data collected by this program are included in the 305(b) Report and the Annual Groundwater Quality Report to the Legislature. In addition, quarterly monitoring results are sent to the Arizona Department of Agriculture.

Wells monitored for pesticides during the past 10 years are shown on **Figure 36**. This map illustrates the following information about pesticides in Arizona:

- Pesticides were detected at levels higher than an Aquifer Water Quality Standard (stars on the map) in only one area. Dibromochloropropane (DBCP) was confirmed in three wells associated with citrus crops in 1994 in the Avondale area.

- Of the 407 wells monitored, pesticides have been detected in 41wells (10%) (triangles and stars on the map).

- In 9% of the wells (37 wells), pesticides were detected but no pesticide standards were exceeded at these wells (triangles on the map), usually because no standard has been established for the pesticide detected.

Monitoring efforts were refocused in 1998 to two areas (Maricopa and Yuma counties) based on the results of the previous ten years of data collection. These areas have had intense agricultural activities, so they are sampled every other year with funding provided by EPA through the Department of Agriculture.

While the focus of the Pesticide Contamination Prevention Program has shifted to known areas of impact, through the ambient groundwater program, pesticide monitoring is still conducted in basin studies where land uses exist to suggest possible impacts.

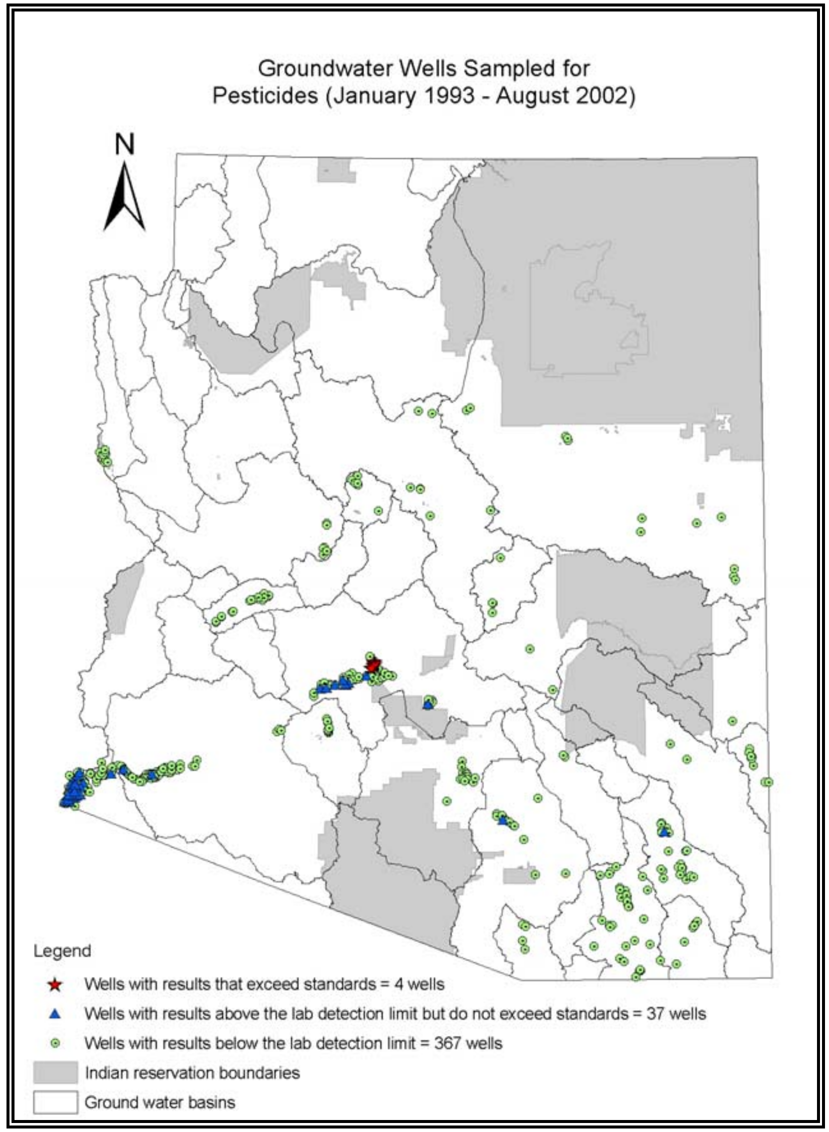

Figure 36. Pesticide Monitoring in Arizona

Ground water quality in Arizona

Most of Arizona's ground water meets Aquifer Water Quality Standards, and thus is suitable for drinking water use. However, there are some ground water quality concerns in Arizona. To provide a general evaluation of ground water quality, this report looks at six constituents in the ground water:

- Pesticides (already discussed in the previous section)
- Arsenic
- Fluoride
- Hardness
- Nitrate
- Radiochemicals (gross alpha and uranium)
- Total dissolved solids (TDS)

Only three of these constituents indicate anthropogenic sources of pollution to ground water when they are elevated (pesticides, TDS, and nitrate). The others are generally found at levels that are natural for ground water. However, most of them (except pesticides and nitrate) are frequently elevated near mining sites where a lot of soil disturbance has occurred, especially where acids have been added to leach out metals. A discussion is provided for each constituent to explain any concerns that may result from elevated concentrations in ground water.

What the Maps Represent -- What these maps really represent is determined by what data are stored in the database and how the database query is made. What is included and what is excluded is equally important in reviewing the maps that follow. Here are the important criteria used for these maps:

- Only data in ADEQ's Water Quality Database were used in constructing these maps. The Database primarily contains data collected by ADEQ's Ambient Ground Water Monitoring Program and the Pesticides Contamination Prevention Program, with a little data from U.S. Geological Survey, the Salt River Project, and the Arizona Department of Water Resources.

- Although some data from Superfund cleanup sites has been entered into the database, this query <u>excluded</u> these data so as to not bias the results towards the areas known to be heavily contaminated. In other words, a disproportionate number of wells were sampled in these areas, so it would appear that these contaminated wells make up a larger proportion of the state than they actually do.

- The data query was made for 10 years, from January 1, 1993 through December 31, 2002.

- All of the wells monitored for a specified constituent were shown.

- Only the data from the <u>last time</u> the well was monitored for that constituent was used.

- Since wells are sampled for varying constituents, the total number of wells sampled for each constituent varies.

- All results reported as "less than" the laboratory reporting level or "non-detection" were considered to be in compliance with Aquifer Water Quality Standards.

Ground Water Standards – The Aquifer Water Quality Standards used in this assessment are shown in **Appendix C.** Generally these ground water standards are identical to the Safe Drinking Water Standards established for public water systems, as well as surface water standards for the Domestic Water Source designated use.

Arsenic – Arsenic is a trace element usually occurring naturally in Arizona's ground water. This constituent is of particular interest since EPA has lowered the health-based, drinking water standard associated with arsenic from 50 µg/L to 10 µg/L effective in 2006. Studies have linked long-term exposure to arsenic in drinking water to cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate. Non-cancer effects of ingesting arsenic include cardiovascular, pulmonary, immunological, neurological, and endocrine (e.g., diabetes) effects.

In general, arsenic can contaminate drinking water through natural processes, such as erosion of rocks and minerals. Arsenic can also contaminate drinking water when used for industrial purposes. Approximately 90 percent of industrial arsenic in the U.S. is currently used as a wood preservative, but arsenic is also used in paints, dyes, metals, drugs, soaps, and semi-conductors. Agricultural applications, mining, and smelting also contribute to arsenic releases in the environment. Arsenic is found at higher levels in underground sources of drinking water than in surface waters, such as lakes, reservoirs, and rivers.

Arsenic concentrations in wells sampled in Arizona between 1994 and 2002 is illustrated on **Figure 37**. The map shows that sampling activity was focused in ground water basins in the southeast and northwest parts of the state, with limited sampling in other parts of Arizona. The graphic reveals the following patterns related to arsenic:

- Generally, sample sites exceeding the present arsenic drinking water standard of 50 µg/L (stars on the map) are found in the Casa Grande area, along the San Simon River and Gila River in the southeastern Arizona, and in scattered areas of Maricopa County. Some exceedances are also present near the communities of Bullhead City, Prescott, and Willcox. Only 3% of wells sampled exceeded the present standard (50 µg/L)

- 15% of the wells sampled will exceed the new standard (10 µg/L) (triangles on the map).

- When the standard is 10 µg/L, the most numerous exceedances will occur in the same areas as occurred under the present arsenic standards; however, almost all areas of the state tested show some degree of arsenic exceedances over the new 10 µg/L standard (triangles on the map).

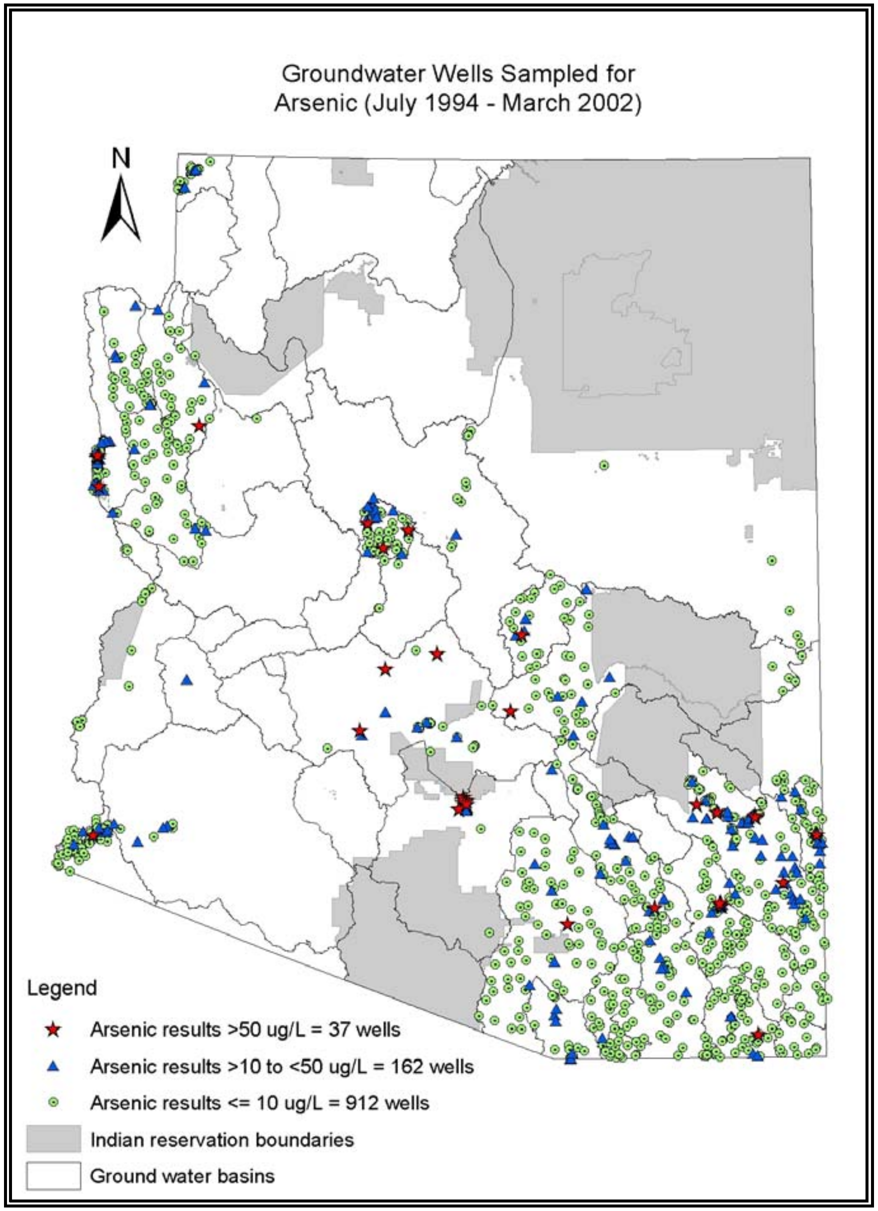

Figure 37. Arsenic Concentrations in Arizona Wells

Arsenic water quality exceedances occur in many different types of aquifers and many types of geology; however, they are most commonly found in soft, sodium-dominated waters that are located in chemically closed hydrologic systems. Thus, some of the most common places for arsenic exceedances are confined or artesian aquifers found in southeastern Arizona.

In a recent publication, *Technologies and Costs for Removal of Arsenic from Drinking Water, EPA 2000*, EPA reviews the types of treatment systems that can be used to remove arsenic. These can be grouped into four broad categories: precipitation process, adsorption process, ion exchange process, and separation (membrane) process. This document and more information about arsenic can be downloaded from EPA's website at www.epa.gov/safewater/arsenic.

Fluoride – Fluoride is another naturally occurring trace element in Arizona's ground water. Fluoride has both a health-based and an aesthetics-based water quality drinking standards associated. EPA has set a health-based water quality standard (or Primary Maximum Contaminant Level [MCL]) for drinking water at 4.0 mg/L. At concentrations higher than this standard, potential health effects include skeletal damage. The EPA has also set an aesthetic guideline (or Secondary MCL) at 2.0 mg/L, because higher levels may cause the mottling of teeth enamel.

Although fluoride at high levels is harmful, fluoride is essential for strong teeth and to prevent tooth decay; therefore, many municipal systems will add fluoride to the water (a process called fluoridation).

Fluoride levels in wells sampled between 1994 and 2002 is illustrated in **Figure 38.** The map reflects that sampling activity was focused in some ground water basins. This map indicates the following information about fluoride in Arizona:

- Fluoride monitoring was focused in ground water basins in the southeast and northwest parts of the state with limited sampling in other parts of Arizona.
- Approximately 4% of wells sampled by ADEQ exceeded the Primary MCL (4 mg/L) (stars on the map), while 17% of wells sampled exceeded the Secondary MCL water quality guideline (2 mg/L) (triangles on the map).

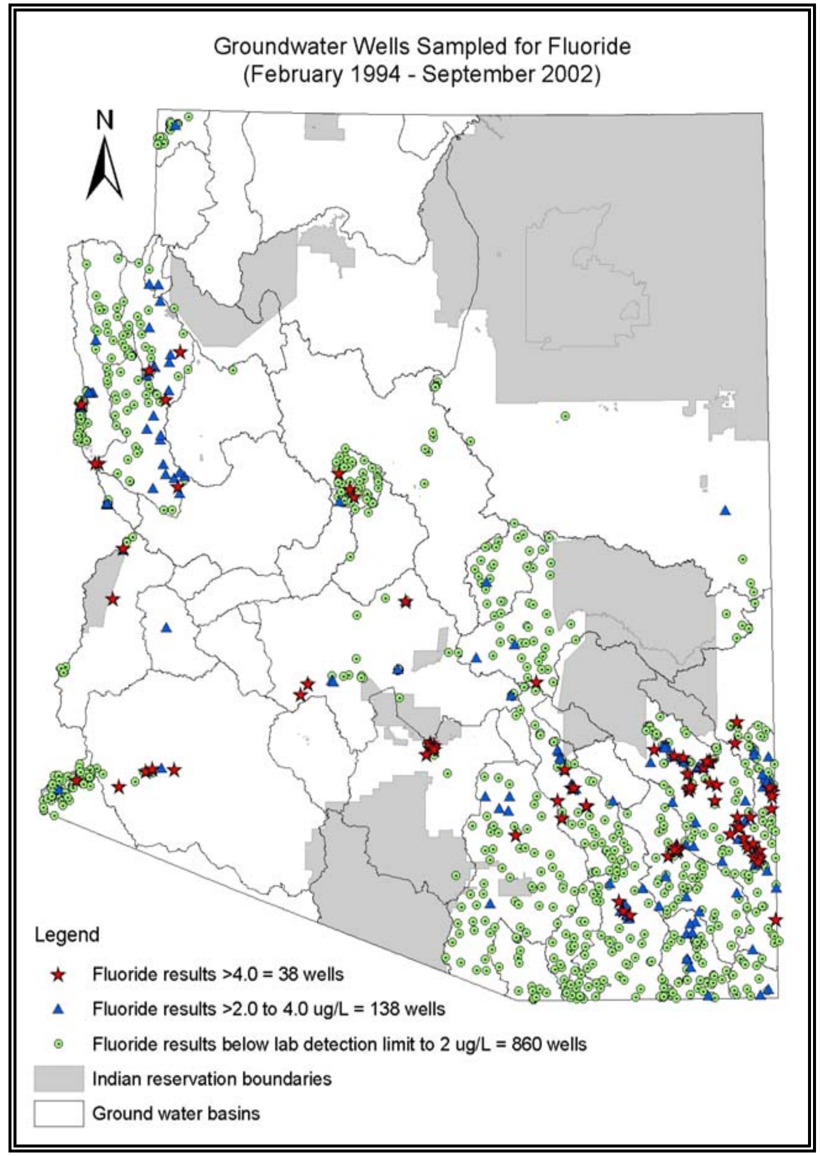

Figure 38. Fluoride Concentrations in Arizona Wells

- Generally, the highest fluoride levels are found in southeastern Arizona in the San Simon, Safford, Duncan, Willcox and San Pedro basins.

- In other parts of Arizona, fluoride concentrations are predominantly below both health and aesthetics-based water quality standards though isolated exceedances of both standards occur in northwestern Arizona and along the lower Gila River.

Most of these elevated levels are associated with confined or artesian aquifers that have chemically closed hydrologic systems. Calcium is an important control of higher fluoride concentrations. In these aquifers, calcium is removed from solution which may result in high concentrations of dissolved fluoride if a source of fluoride ions is available. High fluoride levels found in shallow floodplain wells is often attributed to upward water leakage from confined aquifers. Other sites in southeastern Arizona typically have fluoride concentrations below both health and aesthetics-based water quality standards.

Hardness -- Hardness is an evaluation of certain chemical properties of water that originally represented the soap-consuming capacity of water. The term has now come to denote a more broad measure of the suitability of water for a number of domestic and industrial uses. Modern calculations of hardness usually report it as "calcium-carbonate hardness," which is a measure of the calcium and magnesium dissolved in the water. There are no health or aesthetic-based water quality standards for hardness.

Several hardness classifications exist, but the one most appropriate to Arizona waters is as follows:

• Soft	(below 75 mg/l)
• Moderately hard	(75 to 150 mg/l)
• Hard	(151 to 300 mg/l)
• Very hard	(above 300 mg/l)

"Soft" water, or water low in calcium and magnesium concentrations with sodium as the dominant cation, is desirable for the lack of scale it produces and for other aesthetic reasons. However, soft water has some potentially negative effects as well. For example, when used for irrigation, soft water can potentially create a sodium hazard in the soil which is damaging to the soil structure, especially when high levels of total dissolved solids (TDS) are present.

The softest water is typically found in very deep wells which produce water from confined or artesian aquifers. In contrast to hardrock aquifers, confined aquifers

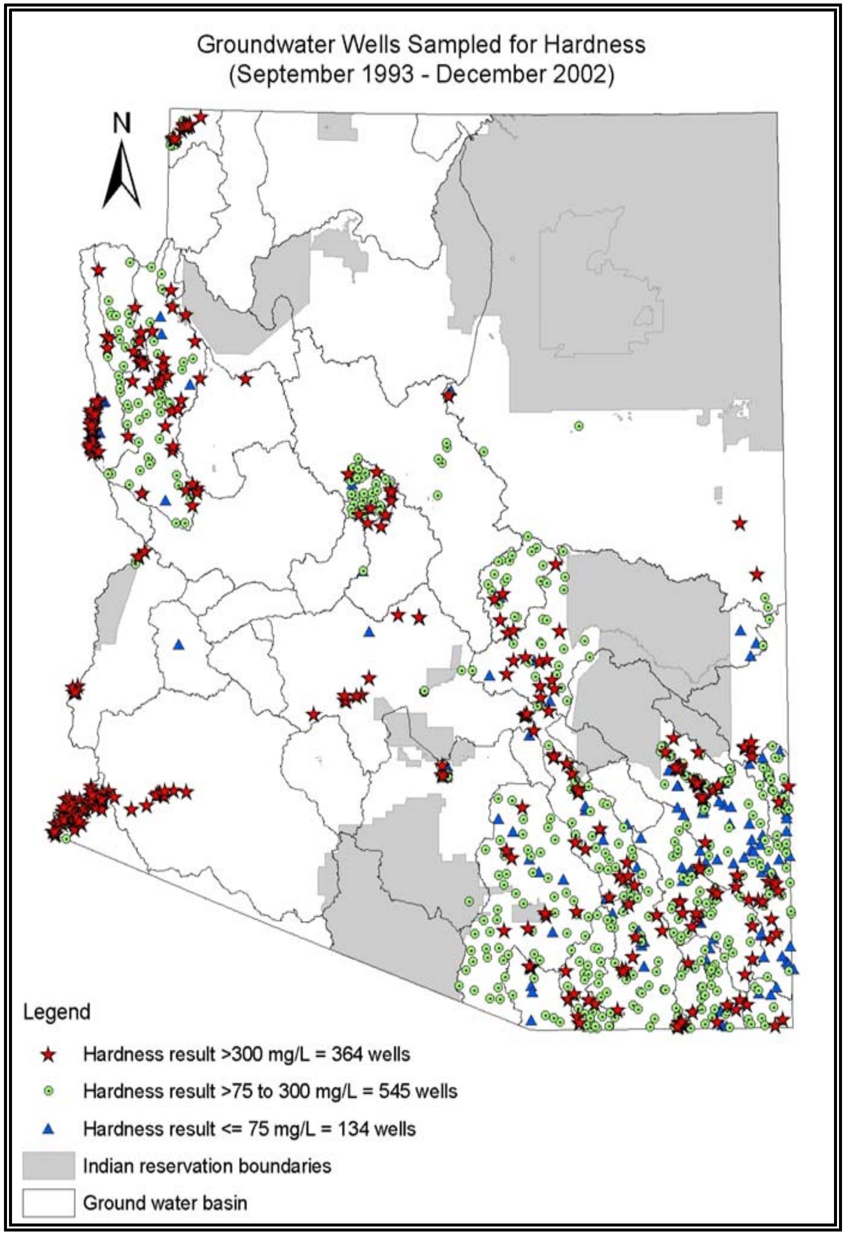

Figure 39. Hardness Concentrations in Arizona Wells

are often chemically closed hydrologic systems that favor the removal of calcium for sodium, producing the "soft" water. This type of soft water may also have elevated concentrations of trace elements such as fluoride and arsenic that may exceed health-based water quality standards.

In basin studies within Arizona, hardness concentrations are often significantly higher at wells located in mountain hardrock as compared with wells located in valley alluvium. Wells in mountain hardrock may have higher hardness concentrations because recharge water has traveled considerable distances underground through weathered, mineralized zones that may create elevated concentrations of dissolved salts and minerals.

The map showing hardness levels of groundwater sites in Arizona between 1993 and 2002 (**Figure 39**) illustrates the following about hardness concentration in Arizona:

- Sampling activity was focused on groundwater basins in the southeast and northwest parts of the state with limited sampling in other parts of Arizona.

- "Very hard" water is most common hardness level. Of the 1,043 groundwater sample sites:
  35% had "very hard" water (stars on the map),
  31% had "hard" water (circles on the map),
  21% had "moderately hard" water (also circles on the map), and
  13% had "soft" water (triangles on the map)

- "Very hard" water is particularly prevalent along the Virgin River near Littlefield, along the Gila River between Buckeye and Yuma, and the Colorado River between Bullhead City and Yuma. However, "very hard" water is found in many other areas throughout the state.

- In the northwest part of Arizona, in ground water basins around Kingman, ground water is generally "moderately hard" to "very hard." The Prescott Active Management Area shows a similar pattern.

- In southeastern Arizona, groundwater sites are more equally divided among the four groups: "very hard," "hard," "moderately hard," and "soft."

The map reflects that sampling activity was focused some of the ground water basins, with limited sampling in other parts of Arizona.

Nitrate – In Arizona, nitrogen typically occurs as nitrate because of the oxidizing nature of most ground water. EPA has set a health-based water quality standard (or Primary MCL) for nitrate (as nitrogen) at 10 mg/L. Drinking water containing nitrate above 10 mg/L (as nitrogen) (may also be measured as 45 mg/L nitrate, as nitrate) should not be consumed by young children or nursing mothers because of possible methemoglobinemia, or "blue baby" health effects.

Nitrate (as nitrogen) concentrations may be divided into the following categories:

- Natural background (< 0.2 mg/L)
- May or may not indicate human influence (0.2 to 3.0 mg/l)
- May result from human activities (3.0 to 10 mg/l)
- Probably results from human activities (> 10 mg/l)

Occurrences of nitrate over 3 mg/L is frequently due to anthropogenic sources such as agricultural practices, septic systems, and other sewage disposal practices. However, some very deep wells in relatively pristine areas have been sampled that have nitrate concentrations over 3 mg/l that probably stem from natural soil organic matter. Thus, careful study must be undertaken before assigning a specific cause to elevated nitrate concentrations.

Figure 40 shows nitrate concentrations in wells sampled between 1994 and 2002. This map illustrates the following:

- Sampling was focused in ground water basins in the southeast and northwest parts of the state, with limited sampling in other parts of Arizona.

- Statewide, only 7% of wells sampled showed nitrate water quality standard exceedances (stars on the map).

- Generally, the highest nitrate concentrations tend to follow an arc starting in the Casa Grande area, through Buckeye, and finally through the lower Gila River area to Yuma. Fortunately, many of these elevated nitrate sites were sampled from shallow monitoring or irrigation wells that are not currently used for drinking water purposes.

- Other sites where nitrate exceeded health-based water quality standards are scattered around Arizona. Some of these can be attributed to shallow wells in other agricultural areas, monitoring wells in areas of dense septic systems use, or isolated windmills situated next to corrals. Most of these nitrate-impacted wells have a shallow depth to groundwater. Deeper wells, however, are not immune to anthropomorphic sources, especially where poor well construction and inadequate seals become routes for pollutants to directly enter the ground water.

Radiochemicals (Gross Alpha and Uranium) – Radioactive elements occur naturally in ground water across Arizona, though their concentrations can be dramatically altered by certain anthropomorphic activities such as hardrock mining. The most common radioactive parameters sampled by ADEQ include gross alpha and uranium. Each of these constituents has an associated health-based water quality standard, or Primary MCL. EPA has set a Primary MCL for gross alpha at 15 piC/L and for uranium at 30 Fg/L for drinking water. At concentrations higher than these standards, potential health effects include various types of cancer and kidney toxicity.

Figure 41 shows relative gross alpha and uranium concentrations in wells sampled between 1994 and 2002. This map illustrates the following information:

- Sampling activity was focused in some of the ground water basins, with limited sampling in other parts of Arizona.

- The map shows a much less dense number of radiochemical samples than other types of parameters. The likelihood of finding elevated radiochemicals, along with the cost of sample analyses, has focused the monitoring on a smaller number of wells within areas where radichemical concentrations are suspected to be high. Radiochemical constituents are more likely to be elevated in mountainous, hardrock areas, particularly in granitic geology; therefore, samples are typically targeted in these areas of granite rock. Samples collected in areas of floodplain alluvium and/or basin-fill have only rarely shown the presence of elevated radiochemical constituents.

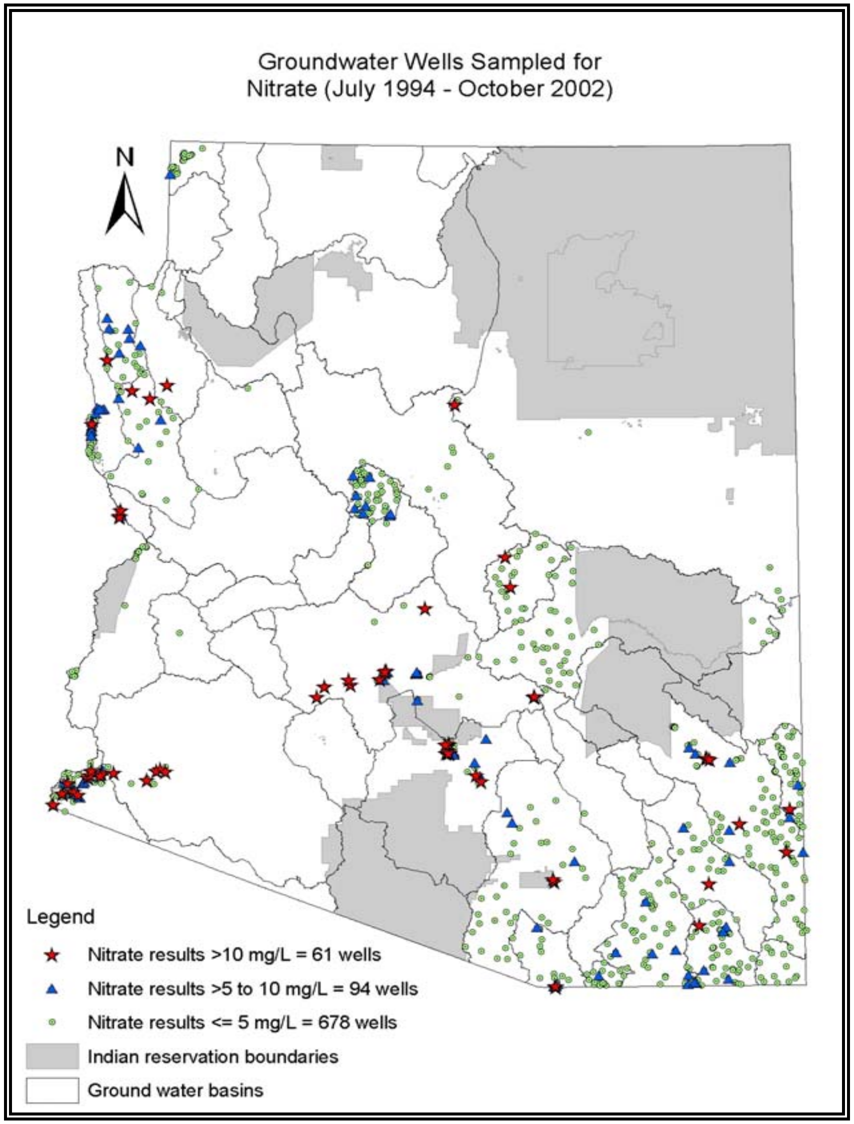

Figure 40. Nitrate Concentration in Arizona Wells

With this semi-targeting of sites, where radiochemical samples are collected, 20% of the wells had exceedances of either gross alpha or uranium standards (stars and triangles on the map).

- Most of the uranium exceedances occur in the Kingman area of northwest Arizona, particularly in the granitic areas of the Cerbat and Hualapai Mountains. The highest concentrations are found near the old mining town of Chloride. In such mining areas, a significant amount of rock containing radioactive elements has been exposed.

- Sample sites in southeastern Arizona have shown occasionally elevated levels of both uranium and gross alpha. Again, most of these exceedances are associated with granitic geology, with the highest levels typically around historic mining areas, such as the community of Dos Cabezas in the Dos Cabezas Mountains.

- Other areas of the state, such as along the Virgin River, in the Prescott AMA, and near Yuma show few, if any, radiochemical standard exceedances.

Total Dissolved Solids – Total dissolved solids, or TDS, is a way to measure the salinity of water. It is the sum of the cations and anions. Thus, this constituent is important because it provides a quick "snapshot" of an area's water quality. While there are no drinking water, health-based water quality standards associated with this constituent, there are both drinking water aesthetic-based water quality guidelines as well as guidelines for irrigation use.

The US Geological Survey classifies water according to the following scale:

• Fresh	(below 1,000 mg/l)
• Slightly saline	(1,000 to 3,000 mg/l)
• Moderately saline	(3,000 to 10,000 mg/l)
• Very saline or briny	(> 10,000 mg/l).

EPA has set an aesthetic guideline for drinking water (Secondary Maximum Contaminant Level or SMCL) at 500 mg/l for TDS. The TDS levels in water at higher levels than the SCML may cause an unpleasant taste in drinking water.

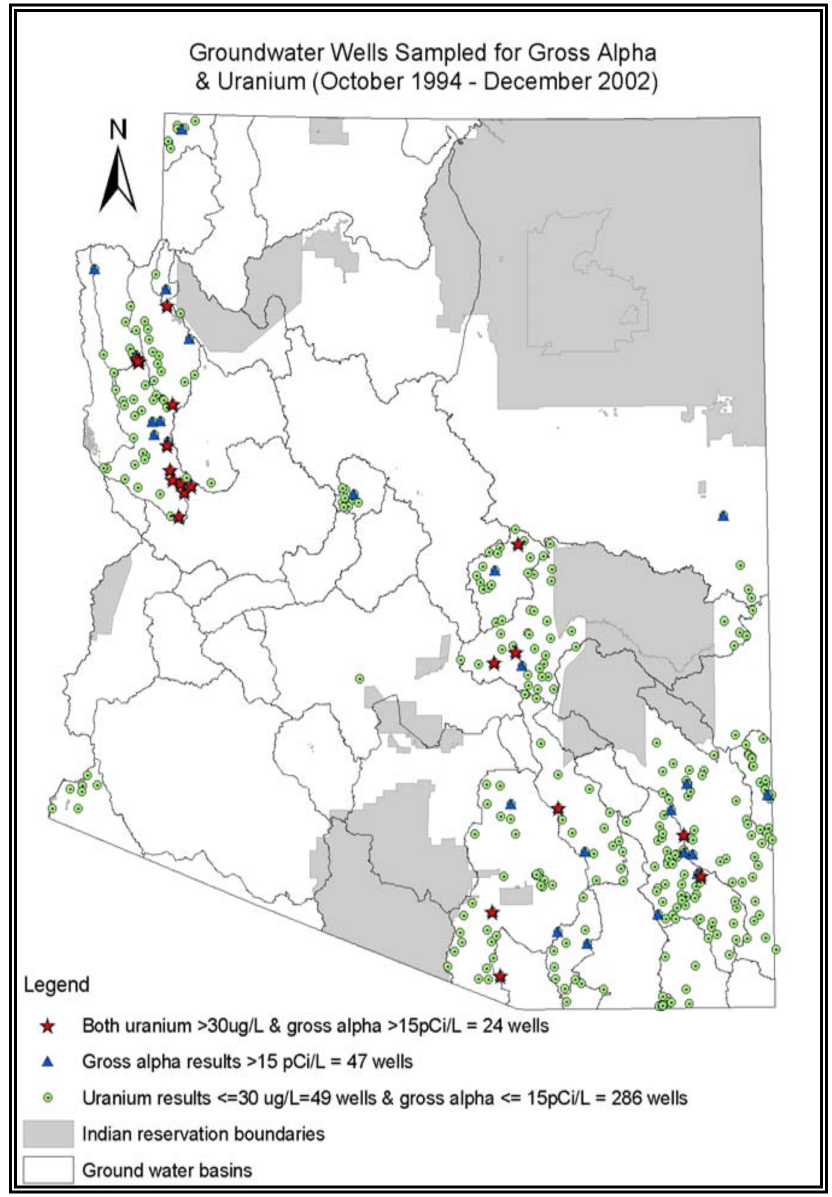

Figure 41. Gross Alpha and Uranium Concentrations in Arizona Wells

For irrigation purposes, the Salt River Project's annual water quality report recognizes that salinity has effects on crop yield according to the following scale:

- No problems with crop yield (< 500 mg/l)
- Increasing problems with crop yield (500 to 2000 mg/l)
- Severe problems with crop yield (> 2000 mg/l).

TDS levels in wells sampled between 1993 and 2002 is shown in **Figure 42**. This map illustrates the following information about TDS concentrations in Arizona:

- Sampling was focused in some of the ground water basins, with limited sampling in other parts of Arizona.

- Of the 1072 ground water sites sampled by ADEQ:
  - < 53% had TDS concentrations below the Secondary MCL standard of 500 mg/L (circles on the map),
  - < 37% were between 500 and 2,000 mg/L (triangles on the map), and
  - < 10% were greater than 2,000 mg/L (stars on the map).

- Generally, the highest TDS levels are associated with agricultural areas along the Colorado, Gila, and Virgin rivers, as indicated by sampling near Buckeye, Fort Mohave, Littlefield, Safford, and Yuma (stars on the map).

- TDS levels in other parts of the state that were extensively sampled (such as southeastern Arizona, the Prescott AMA, and around Kingman) generally have levels below 2,000 mg/l, with the majority of sample sites below the 500 mg/l drinking water aesthetic guideline level.

Deterioration of ground water quality, as represented by increasing TDS levels, has been well documented in many studies. Salts present in the initial irrigation water applied become concentrated by evapotranspiration in the small amount of water that is recharged to the aquifer. These salt loadings on aquifers are exacerbated in river valleys, which typically have shallow ground water levels.

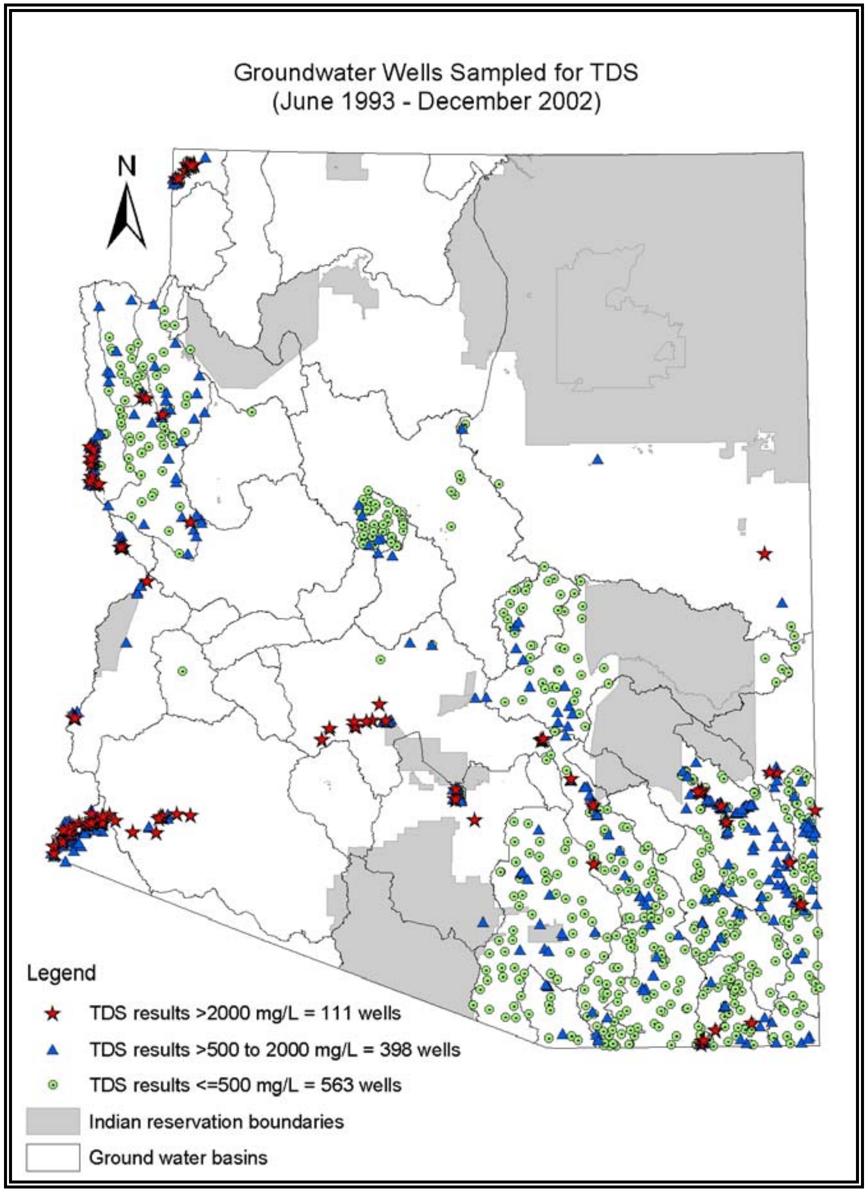

Figure 42. TDS Concentrations in Arizona Wells